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# Implementation of Bacterial Foraging Algorithm for Enhancing Voltage Profile and Loss Minimization using Static Var Compensator

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**ABSTRACT**

**Now a day demand of Electricity has been increased abruptly. Inorder to overcome those demand, adaptation of renewable energy has becomes a new era. Since the grid network become enlarging along with the transmission losses. Minimization of Transmission loss is very much important for the power system. By ensuring the reactive power compensation leads to the minimization of transmission losses. Increasing of demand in the electric power system leads to the Voltage profile deviation. This phenomenon creates decrease in voltage profile below the stability limit. Due to the inventory of FACTS device leads to the enhancement of voltage profile in preferred limits but also it helps to compensate the real power loss minimization in the electrical network. Since the optimal placing of FACTS device becomes tedious process, to overcome this difficulties we adopting a new search technique is Bacteria Foraging Algorithm (BFA) is adopted. This paper presents optimal sizing of FACTS device, which is attained by the searching technique of bacteria foraging along with optimal sizing of FACTS device. Static Var Compensator (SVC) is one of the FACTS device, employed for improvement of voltage profile and loss minimization. The specific design of SVC provide the real power loss minimization along with increase of voltage profile. The proposed algorithm is made evaluated in IEEE 14 and IEEE 30 bus system. The test results are describes that enhancement of voltage profile along with loss minimization in the transmission line.**

*Keywords* – **Bacteria Foraging Algorithm , loss minimization , Satic Var Compensator ,Voltage profile**

## I. INTRODUCTION

The increased demand for electric power and the insufficient power generation and transmission facility forces the power system networks being operated under stressed conditions. In recent days ,the voltage instability has become a challenging task to power system planning and operation. When current flows through the transmission line and a line have a finite resistance there is an unavoidable power loss. This is sometimes called as conductor loss or conductor heating loss and is simply a power loss. Voltage stability refers to the ability of a power system to maintain voltage such that when the load demand is increased, the load power also increases and both power and voltage are controllable [1].When the voltages at the system buses are low, the losses will also be increased. This study is devoted to develop a technique for improving the voltage and minimizing the losses and hence eliminate voltage instability in a power system [2]. The transmission loss is reduced and voltage profile is improved while satisfying a given set of operating and physical constraints [3]-[4]. Unavailability of sufficient reactive power sources to maintain normal voltage profiles at heavily loaded buses are the prime reasons for the voltage collapse.

Apart from the aforesaid methods, the transmission line loss can also be reduced simply shortening the length of the transmission line or by increasing the diameter of the transmission line for improving the stability of a power system. FACTS devices are used to control the power flow in the transmission lines as well as the bus voltages. Several efforts have been made to find the ways to assure the security of the system in terms of voltage stability. It is found that flexible AC transmission system (FACTS) devices are a good choice to improve the voltage stability in power systems. There are several advantages in power system operation and planning Such advantages include the minimization of system losses, elimination of line overloads and low voltage profiles. Recently, the Evolutionary Computation (EC) in the solution of complex problems such as Differential Evolution (DE) [5], Particle Swarm Optimization (PSO) [6], Ant Colony Optimization (ACO), and Genetic Algorithms (GAs) are some of the heuristic techniques having great convergence characteristics and capability of determining global optima. F.G.Bagriyanik et.al [7] proposed a technique for power loss minimization based on Genetic Algorithm using TCSC. R.Benabid and M.Boudour [8] proposed an application of NSPSO to solve the optimal location and size of SVC and TCSC for voltage stability enhancement.

This paper, proposes a method for finding the optimal location and design of Static Var Compensator (SVC) using Bacterial Foraging algorithm in order to minimize the real power loss and voltage profile improvement. Chang and Huang [9] proposed a hybrid optimization scheme applying parallel simulated annealing and a Lagrange multiplier for optimal SVC planning to enhance voltage profile. This paper, proposes a method for finding the optimal location and design of Static Var Compensator (SVC) using Bacterial Foraging algorithm in order to achieve the objective function of minimization of real power loss, voltage profile improvement. The proposed algorithm has been tested on IEEE 14-bus and IEEE 30-bus reliability test systems. A load flow program written in MATLAB using bacterial foraging technique was used to compute power flow. The effectiveness and efficiency of the proposed techniques is established giving different test results of IEEE standard systems.

This paper is organized as follows: Section 2 describes the modeling of SVC. Section 3 deals with problem formulation which relates the objective function. Bacteria foraging algorithm for proposed system is given in section 4. Results are discussed in section 5.Finally conclusion are presented in section 6.

## II. MODELING OF SATIC VAR COMPENSATOR (SVC)

Static Var Compensator is a shunt connected FACTS device, which play a major role to regulate voltage profile at the give bus and to reduce the real power loss by adjusting the reactance value of it. SVC composed of fixed capacitor (FC) and thyristor controlled reactor (TCR).

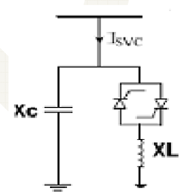



Fig. 1. Equivalent circuit of SVC

In the equivalent circuit of SVC, it is seen that it has parallel connection of capacitor and reactance. Herein it has the capability to act in capacitor mode or inductor mode to ensure the objective function. The reactance Xsvc is assumed as a function of tuning the firing angle of TCR, since it is made parallel connection to fixed capacitor. Evaluation of SVC parameter becomes major task for enhancement of Voltage profile and real power loss minimization in transmission line. The value of capacitor and the TCR inductive value are formulated as,

$$X_c = \frac{V^2 bus}{Qsvc}\ ,\ X_L = \frac{X_c}{2}\ ,\ X_{svc} = \frac{X_c X_{TCR}}{X_c + X_{TCR}} \tag{1}$$

## III. Problem Formulation

The objective function of this work is to find the optimal location and size of SVC which minimizes the real power loss and voltage deviation.

$$F=[f1, f2] \tag{2}$$

$$f_1 = \sum_{k \in Nl} g_k (V_i^2 + V_j^2 - 2V_i V_j \cos\theta_{ij}) = P_{loss}^l \tag{3}$$

$$f_2 = VD = \sum_{k=1}^{N_{PQ}} (V_k - Vref_k)^2 \tag{4}$$

The first term f1 represents real power loss

The second term f2 represents the total voltage deviation (VD) of all load buses from desired value of 1 p.u.

The minimization problem is subject to the following equality and inequality Constraints:

i) Load flow constraints

$$P_i - V_i \sum_{j=1}^{Ng} V_j (G_{ij} \cos\theta_{ij} + B_{ij} \sin\theta_{ij}) = 0, i = 1, 2, ......N_B - 1 \tag{5}$$

$$Q_i - V_i \sum V_j (G_{ij} \sin\theta_{ij} - B_{ij} \cos\theta_{ij}) = 0, i = 1, 2, ......N_{PQ} - 1 \tag{6}$$

ii) Voltage constraints

$$V_i^{\min} \le V_i \le V_i^{\max}; i \in N_B \tag{7}$$

iii) Reactive power generation limit

$$Q_{gi}^{\min} \le Q_{gi} \le Q_{gi}^{\max}; i \in N_g \tag{8}$$

iii) Transmission line flow limit

$$S_i \le S_i^{\max}; i \in N_l \tag{9}$$

## IV. Bacteria Foraging Algorithm

Foraging theory is based on the natural behavior of animal searching for their nutrient which maximize their energy for foraging [10]. This algorithm is based on the searching behavior of E.Coil bacteria. E.coil is a microorganism which has the nature of searching of food more quicker than other. Chemotaxis is the natural foraging behavior of bacteria, which helps to catch the required nutrient. Implementation of chemotaxis steps, the searching process are followed.

Let j be the steping rate of chemotaxis, k be the reproduction step and l be the index of elimination dispersal event. The length of life time of bacteria Nc is measured by the number of chemotoxix steps. Bacteria swims in the free space to reduce loss, along with maximum number of steps Ns. Next to the chemotaxis reproduction is adopted. Nre is the number of reproduction steps to be taken by bacteria for population sorting. Inorder to make increase of population of bacteria reproduction is carried out. This method provides bacteria with a lot of nutrients and also keeps the population size constant.

For initialization, you must choose *p*, *S*, *Nc* , *Ns* , *Nre* , *Ned* , *ped* , and the *C*( *i*), *i* = 1,2,K, *S*. If you use swarming, you will also have to pick the parameters of the cell-to-cell attractant functions; here we will use the parameters given above. Also, initial values for the θ*i* , *i* = 1,2,K, *S*, must be chosen. Choosing these to be in areas where an optimum value is likely to exist is a good choice. Alternatively, you may want to simply randomly distribute them across the domain of the optimization problem. The algorithm that models bacterial population chemotaxis, swarming, reproduction, elimination, and dispersal is given here (initially, *j* = *k* = *l* = 0). For the algorithm, note that updates to the θ*i* automatically result in updates to *P*. Clearly, we could have added a more sophisticated termination test than simply specifying a maximum number of iterations. Algorithm were as follows,

STEP 1: Elimination-dispersal loop: l = l + 1

STEP 2: Reproduction loop: k = k + 1

STEP 3: Chemotaxis loop: j = j + 1

For i = 1,2,K,S, take a chemotactic step for bacterium i as follows.

Compute J(i,j,k,l). Let J(i,j,k,l) = J(i, j,k,l)+ J cc(θi(j,k,l), p( j,k,l )) (i.e., add on the cell-to-cell attractant effect to the nutrient concentration).

Let J last = j(i,j,k,l) to save this value since we may find a better cost via a run.

Tumble: Generate a random vector Δ( i) ∈ _p with each element m(i),m = 1,2,K,p, a random number on [−1,1].

Move: Let

$$\theta^{i}(j+1,k,l)=\theta^{i}(j,k,l)+C(i)\frac{\Delta(i)}{\sqrt{\Delta^{T}(i)\Delta(i)}} \qquad (10)$$

This results in a step of size C(i) in the direction of the tumble for bacterium i.

Compute J( i, j + 1,k,l), and then

let J( i, j + 1,k,l) = J(i,j+1,k,l)+Jcc(θi(j+ 1,k,l),P(j+1,k,l)).

Swim (note that we use an approximation since we decide swimming behavior of each cell as if the bacteria numbered {1,2,K,i} have moved and {i + 1,i + 2,K, S} have not; this is much simpler to simulate than simultaneous decisions about swimming and tumbling by all bacteria at the same time.

Let m=0 (counter for swim length).

While m<Ns (if have not climbed down too long)

Let m=m+ 1.

If J(i,j+1,k,l) <Jlast (if doing better), let Jlast= J(i,j+1,k,l) and let

$$\theta^{i}(j+1,k,l)=\theta^{i}(j+1,k,l)+C(i)\frac{\Delta(i)}{\sqrt{\Delta^{T}(i)\Delta(i)}} \qquad (11)$$

Else, let m= Ns. This is the end of the while statement.

Go to next bacterium (i + 1) if i ≠ S (i.e., go to b) to process the next Bacterium).

If j < Nc, go to step 3. In this case, continue chemotaxis, since the life of the bacteria is not over.

Reproduction:

a) For the given k and l, and for each i = 1,2,K, S, let be the health of bacterium i (a measure of how many nutrients it got over its lifetime and how successful it was at avoiding noxious substances). Sort bacteria and chemotaxis parameters (i) in order of ascending cost Jhealth (higher cost means lower health).

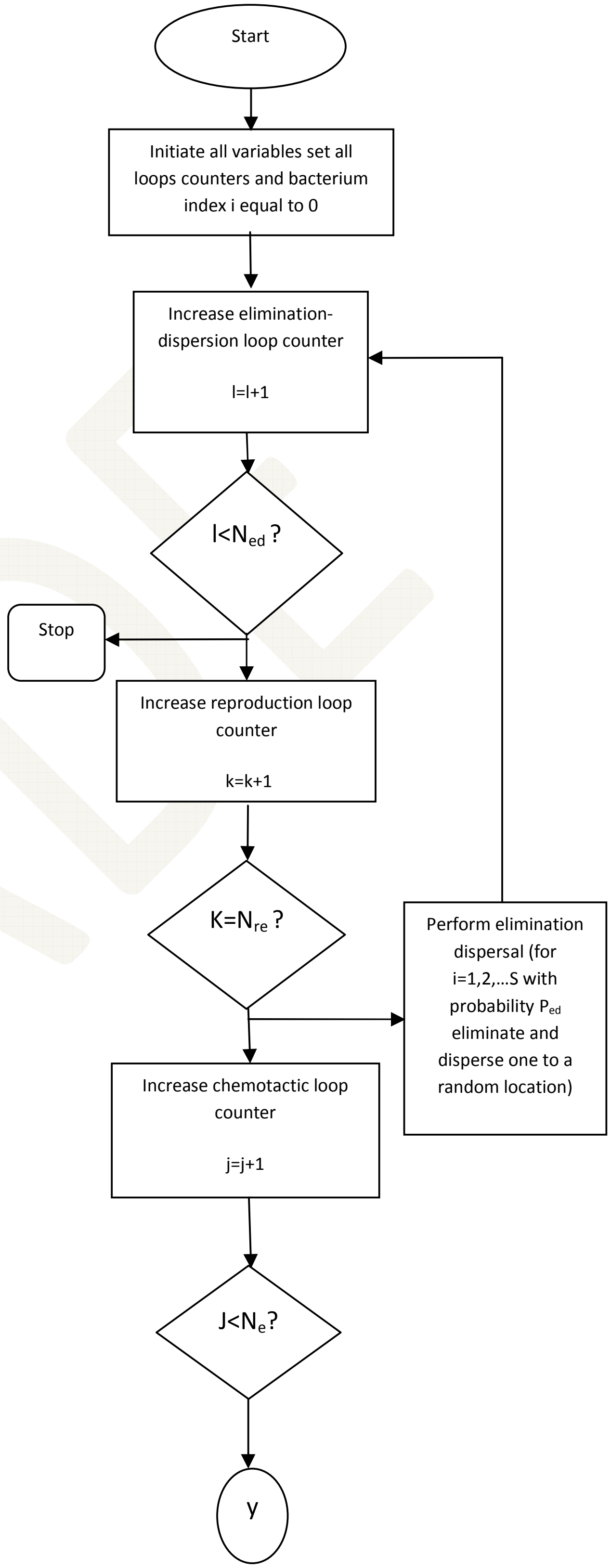
$$J^{i}_{health} = \sum_{j=1}^{N_c+1} J(i,j,k,l) \qquad (12)$$

b) The Sr bacteria with the highest Jhealth values die and the other Sr bacteria with the best values split (and the copies that are made are placed at the same location as their parent).

STEP 4: If k < Nre, go to step 2. In this case, we have not reached the number of specified reproduction steps, so we start the next generation in the chemotaxis loop.

STEP 5: Elimination-dispersal: For i = 1,2,K, S, with probability ped , eliminate and disperse each bacterium (this keeps the number of bacteria in the population constant). To do this, if you eliminate a bacterium, simply disperse one to a random location on the optimization domain.

STEP 6: If l<Ned, then go to step 1; otherwise end.



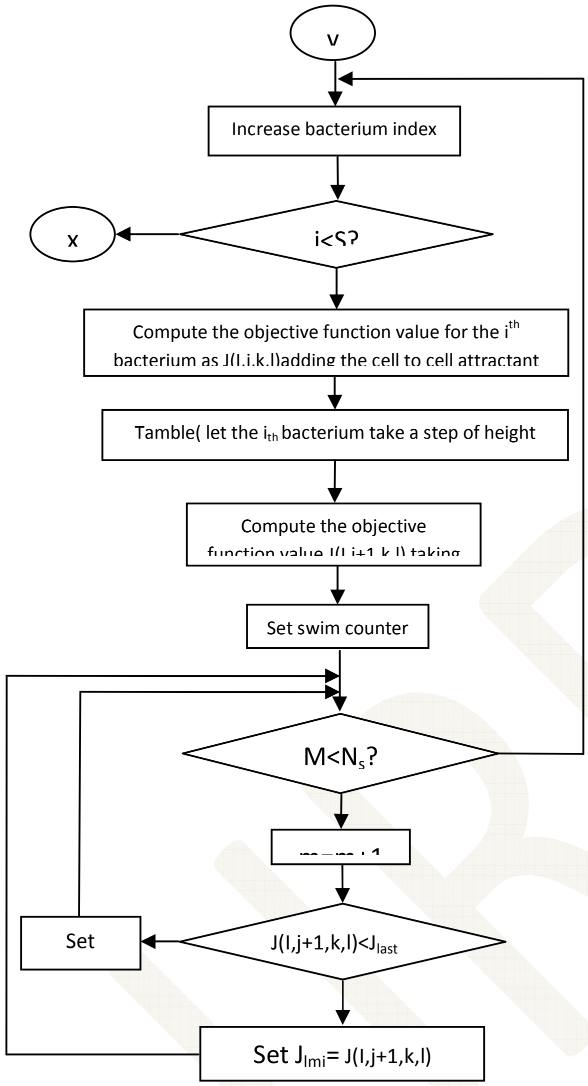



Fig.3. Flow Chart of Bacteria Foraging Algorithm.

Table 1.2. Control Parameter of the BFA

| S.No | Parameter | Values |
|---|---|---|
| 1 | Number of bacteria, S | 20 |
| 2 | Maximum no. of. Steps, Ns | 4 |
| 3 | No. of. Chemotactic steps, Nc | 20 |
| 4 | No.of. reproduction steps, Nre | 4 |
| 5 | No.of elimination- disperse steps, Ned | 2 |
| 6 | Probability, Ped | 0.25 |

## V. RESULT AND DISCUSSION

BFA has been coded as M-file in MATLAB platform. Base MVA of the system is 100MVA and the reference bus is taken as bus node 1. In order to verify the algorithm the network are made with critical loading condition. The results are shown that, losses minimization and voltage profile enhancement has made. Here the optimal placement of SVC has been carried out in 9$^{th}$ bus to overcome losses and voltage profile improvement in IEEE 14 bus system. IEEE 14 bus system consist of 5 Generator bus and 9 load bus with 20 transmission line along with 3 tap changing transformer. Here in testing of network since the IEEE 14 bus system are made to be critically loaded in order to make observation of BFA for the enhancement of voltage profile and real power loss minimization.

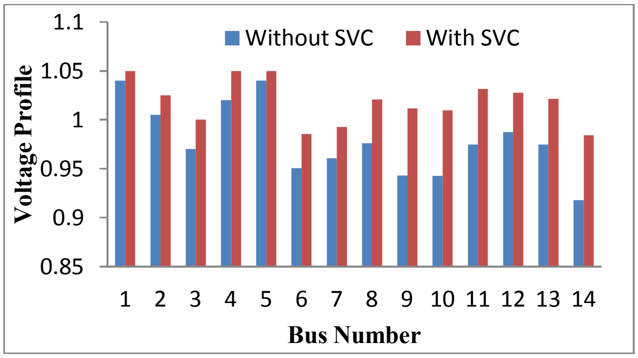



Fig.1. Voltage profile improvement in IEEE 14 bus system.

From Fig.1. it is observed that voltage profile of entire system has made enhanced within the accepted limits. Although the real power loss are minimized as shown in table.1.

Table.1.Real power loss minimization in IEEE 14 bus System.

| Load Condition | Before SVC | After SVC |
|---|---|---|
| Critical load condition | 18.9701 MW | 17.169 MW |

Inference from table.1 shows that real power loss minimization is carried out for about 1 MW under critical load condition. Hence the optimal placement of SVC is at 9th bus, which has been obtained by the searching algorithm of Bacteria foraging algorithm.

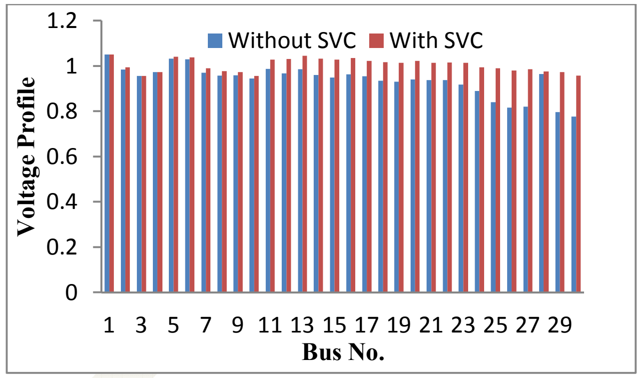



Fig.2. Voltage Profile improvement in IEEE 30 bus system

Fig.2. shows that the test result of Voltage profile enhancement under critical load condition in IEEE 30 bus system. IEEE 30 bus system consists of 6 Generator bus, 4 transformer tap positions and 2 shunt VAR compensator. Voltage profile of IEEE 30 bus system is made enhanced by optimal placing of SVC by BFA.

Table.2. Real power loss minimization in IEEE 30 bus system

| Load Condition | Before SVC | After SVC |
|---|---|---|
| Critical load condition | 1.74 MW | 0.719 MW |

From Table.2. it is observed that real power loss is made upto 1 MW in IEEE 30 bus system. Since the optimal placement of SVC is at 30th bus and its make ensure of real power loss minimization.

## VI. CONCLUSION

In this paper an attempt is made for the optimal location and optimal sizing of SVC has been made to enhance voltage profile and to minimize the real power losses in the power system. The test systems are shown the validation of results for voltage profile deviation enhancement and real power loss minimization. This result also shows that, BFA has effective behaviour for voltage profile enhancement and real power loss

minimization in power system. Since BFA shows that excellence result for Voltage profile enhancement and loss minimization when compare to other conventional technique. From the results analysis it is concluded that SVC improve the system performance of the electrical network.

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